(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 February 2005 (10.02.2005)

PCT

(10) International Publication Number
WO 2005/012346 A1

(51) International Patent Classification[7]: C07K 14/62, 14/765, A61P 3/10, C07K 1/113, A61K 38/28, A61P 5/50

(21) International Application Number:
PCT/CA2004/001409

(22) International Filing Date: 26 July 2004 (26.07.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/490,110 25 July 2003 (25.07.2003) US
60/556,585 25 March 2004 (25.03.2004) US

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: LONG LASTING INSULIN DERIVATIVES AND METHODS THEREOF

(57) Abstract: The present invention relates to an insulin derivative comprising an insulin molecule and a reactive group for covalently bonding a blood component, wherein preferably the insulin molecule is human natural insulin molecule and the reactive group is coupled to an amino acid of the insulin molecule at a position selected from the positions Gly A1, Phe B1 and Lys B29.

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LONG LASTING INSULIN DERIVATIVES AND METHODS THEREOF

BACKGROUND OF THE INVENTION

(a) Field of the Invention

[0001] This invention relates to a long lasting insulin derivative. More particularly, the insulin derivative comprises an insulin molecule and a reactive group coupled thereto, the reactive group being for covalently bonding a blood component hence generating a long lasting insulin derivative.

(b) Description of Prior Art

[0002] Insulin is a vital endocrine hormone that binds to a cellular surface receptor setting off a cascade of events culminating in glucose absorption from the blood. Impaired levels of insulin lead to severe disorders such as types I and II diabetes. Type I diabetes is a life threatening disease where the patient must daily self-administer multiple doses insulin for survival. Type II diabetes, is also a severe medical disease where the endogenous levels of insulin can no longer maintained correct levels of glycemia because the patient due to a tolerance developed by the patient to endogenous levels of insulin. In order to reduce the onset of long-term consequences, a treatment with insulin becomes necessary after failure in lifestyle changes or when traditional glycemia controlling drugs become ineffective.

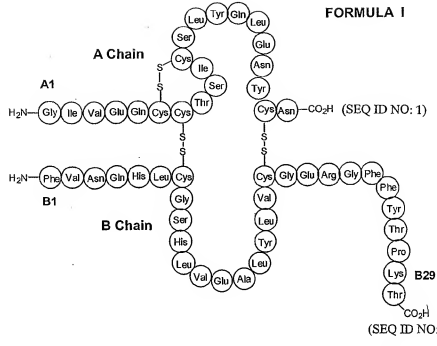
[0003] Success in the control of glycaemic disorder is highly related with the compliance of patients to the treatment, and reducing the frequency of injection needed is desirable. To do so, it would be highly desirable to be provided with a new long lasting insulin derivative.

SUMMARY OF THE INVENTION

[0004] In accordance with the present invention there is provided an insulin derivative comprising an insulin molecule and a reactive group for covalently bonding a blood component.

[0005] In a preferred embodiment of the present invention, the insulin molecule is of formula I:

FORMULA I



[0006] and the reactive group is coupled to an amino acid of the insulin molecule at a position selected from the positions Gly A1,Phe B1 and Lys B29.

[0007] In a preferred embodiment of the present invention, the reactive group selected are from the group consisting of Michael acceptors (α,β, unsaturated carbonyl moiety) succinimidyl-containing group and maleimido-containing groups, more preferably MPA (3-MaleimidoPropionic Acid).

[0008] In a preferred embodiment of the present invention, the reactive group is coupled to an amino acid of the insulin molecule via a linker, such as, but not limited to (2-amino) ethoxy acetic acid (AEA), ethylenediamine (EDA), amino ethoxy ethoxy succinimic acid (AEES), AEES-AEES, 2-[2-(2-amino)ethoxy)] ethoxy acetic acid (AEEA), AEEA-AEEA, -NH_2-$(CH_2)_n$-COOH where n is an integer between 1 and 20 and alkyl chain (C1-C10) motif saturated or unsaturated in which could be incorporated oxygen nitrogen or sulfur atoms, such as, but not limited to glycine, 3-aminopropionic acid (APA), 8-aminooctanoic acid (OA) and 4-aminobenzoic acid (APhA)and combination thereof.

[0009] In a preferred embodiment of the present invention, the blood component is a blood protein, more preferably is serum albumin.

[0010] In accordance with the present invention, there is provided an insulin conjugate comprising an insulin derivative of the present invention and a blood component, wherein the reactive group and the blood component are conjugated through a covalent bond formed between said reactive group and said blood component. This conjugate is formed *in vivo* or *ex vivo*.

[0011] In accordance with the present invention, there is provided a pharmaceutical composition comprising the insulin derivative of the present invention in association with a pharmaceutically acceptable carrier.

[0012] In accordance with the present invention, there is provided a pharmaceutical composition comprising the insulin conjugate of the present invention in association with a pharmaceutically acceptable carrier.

[0013] In accordance with the present invention, there is provided a method for treating a glycaemic-related disease or disorder in a subject suffering from said glycaemic-related disease or disorder, comprising administering at least one of the insulin derivatives of the present invention, the conjugate of the present invention and the pharmaceuticals compositions of the present invention to the subject.

[0014] All references herein are hereby incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Fig. 1 illustrates example I to example VIII derived from native human insulin;

[0016] Fig. 2 illustrates competitive binding of insulin, insulin derivatives and conjugate of insulin derivatives on liver membranes of wistar rats;

[0017] Fig. 3 illustrates competitive binding of insulin, insulin derivatives and conjugate of insulin derivatives on liver membranes of wistar rats;

[0018] Fig 4A, 4B, 4C 5A,5B 6A,6B present various phases of 3T3 L1 adipocytes differenciation stages

[0019] Fig. 7 illustrates glucose transport in 3T3-L1 adipocytes for insulin, example III and IV and their corresponding conjugate

[0020] Fig. 8 illustrates glucose transport in epididymal fat cells from wistar rats adipocytes for insulin, example III and VI and their corresponding conjugate

[0021] Fig. 9 illustrates delta glycaemia in function of time in animals treated with insulin at 3.6 mg/kg;

[0022] Fig. 10 illustrates delta glycaemia in function of time in animals treated with insulin derivatives of examples I, II and III at 3.6 mg/kg;

[0023] Fig. 11 illustrates delta glycaemia in function of time in animals treated with insulin derivatives of examples I, II and III at 17.9 mg/kg;

[0024] Fig. 12 illustrates delta glycaemia in function of time in animals treated with insulin and insulin derivative of example I at 3.6 mg/kg and insulin derivative of example I at 17.9 mg/kg;

[0025] Fig. 13 illustrates delta glycaemia in function of time in animals treated with insulin and insulin derivative of example II at 3.6 mg/kg and insulin derivative of example II at 17.9 mg/kg;

[0026] Fig. 14 illustrates delta glycaemia in function of time in animals treated with insulin and insulin derivative of example III at 3.6 mg/kg and insulin derivative of example III at 17.9 mg/kg;

[0027] Fig. 15 illustrates the pharmacokinetic profile of native insulin injected subcutaneously and intravenously;

[0028] Fig. 16 illustrates the pharmacokinetic profile of conjugate of example III injected subcutaneously and intravenously;

[0029] Fig. 17 illustrates the pharmacokinetic profile of example III injected subcutaneously and intravenously;

[0030] Fig. 18 illustrates comparative pharmacokinetic profile of insulin, example III and conjugate of example III injected subcutaneously;

[0031] Fig. 19 illustrates comparative pharmacokinetic profile of insulin, example III and conjugate of example III injected intravenously;.

[0032] Fig. 20 illustrates comparative pharmacodynamic profile post subcutaneous injections of insulin, example I to IV and vehicule in streptozocin induced diabetic rat;

[0033] Fig. 21 illustrates comparative pharmacodynamic profile post subcutaneous injections of insulin, the conjugate of example I to IV and vehicule in streptozocin induced diabetic rat;

[0034] Fig. 22 illustrates comparative pharmacodynamic profile of repeated subcutaneous injections of example III (day1 versus day 6 versus day12 versus control); and

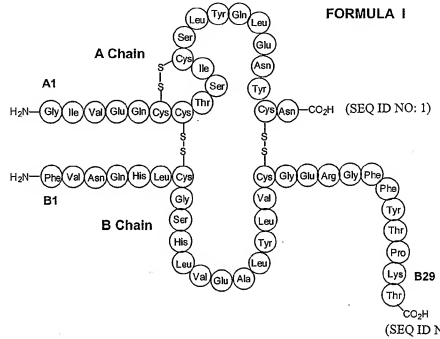
[0035] Fig. 23 illustrates comparative pharmacodymanic profile of repeated subcutaneous injections of the conjugate of example III (day1 versus day 6 versus day12 versus control).

DETAILED DESCRIPTION OF THE INVENTION

[0036] In accordance with the present invention, there is provided a long lasting insulin derivative. More particularly, the insulin derivative comprises an insulin molecule and a reactive group coupled thereto, the reactive group being for covalently bonding a blood component. In the present application, it is intended that the covalently bonding, resulting in the formation of a conjugate insulin-reactive group –blood component can be formed *in vivo* upon administration of the insulin derivative of the present invention. It is also intended that the covalently bonding can occur *ex vivo* by contacting the insulin derivative of the present invention with a source of albumin that can be recombinant albumin, or extracted from a subject's plasma, or providing from any other suitable source, which source would be known by one skilled in the art.

[0037] The insulin molecule may be native human insulin (see the sequence of native human insulin below in Formula I) or an analogue thereof such as an insulin molecule with amino acid substitution(s), amino acid deletion(s) or amino acid addition(s). The following are listed as examples of insulin analogue that can be used in accordance with the present invention without the intention to limit the present analogue in any way: insulin glargine called Lantus® of Aventis Pharmaceuticals Inc., which has a glycine substituted in position A21 and two residues of arginine added in C-terminus of the chain B; insulin detemir called Levemir® of Novo Nordisk A/S, which is a native human insulin where threonine in position B30 is deleted and tetradecanoyl is added on the lateral chain of lysine B29; insulin lispro called Humalog® of Eli Lilly, which

is Lys B28, Pro B29 human insulin; insulin aspart called NovoLog® of Novo Nordisk A/S, which Asp B28 human insulin; and insulin glulisine called Apidra® of Aventis, which is Lys B3, Glu B29 human insulin.



[0038] The reactive group may be coupled to different functionalities on the insulin molecule or analogue thereof. Preferably, the reactive group is coupled to an available amino group of the insulin molecule, such as the α-amino groups of the N-terminus amino acid of chains A and B, or the ϵ-amino group of Lys B29. In accordance with the invention, insulin analogue containing substituted and/or added amino acid(s) may contain additional amino group for coupling the reactive group; or other functionalities appropriate for coupling the reactive group thereto. Preferred reactive groups capable to covalently bond a blood component in vivo or ex vivo, are Michael acceptors (α,β, unsaturated carbonyl moiety) succinimidyl-containing groups and maleimido-containing groups. The more preferred reactive group is a maleimido-containing group, and more particularly MPA (3-MaleimidoPropionic Acid).

[0039] Optionally, the reactive group is optionally coupled to the insulin molecule via a linker. The linker is preferably selected from the group consisting of hydroxyethyl motifs such as (2-amino) ethoxy acetic acid

(AEA), ethylenediamine (EDA), amino ethoxy ethoxy succinimic acid (AEES), 2-[2-(2-amino)ethoxy)] ethoxy acetic acid (AEEA), AEEA-AEEA, -NH2-(CH2)n-COOH where n is an integer from 1 to 20; one or more alkyl chains (C1-C10) saturated or unsaturated in which could be incorporated oxygen nitrogen or sulfur atoms motifs such as glycine, 3-aminopropionic acid (APA), 8-aminooctanoic acid (OA), 4-aminobenzoic acid (APhA). Examples of combinations of linkers include, without limitations, AEEA-EDA, AEEA-AEEA, AEA-AEEA, AEES-AEES, and the like. The preferred linker is 8-aminooctanoic acid (AOA) or the use of no linker with the reactive group MPA. One skilled in the art would readily know what type of linker is suitable for the purpose of the present invention.

[0040] The present invention also relates to an insulin conjugate. The conjugate comprises an insulin derivative where its reactive group has reacted with a blood component *in vivo* or *ex vivo* so as to form a covalent bond. Therefore, the conjugate may be formed *in vivo* by the administration of the insulin derivative, or *ex vivo* by contacting the insulin derivative to a blood solution or purified blood components *ex vivo* in conditions that allow formation of the covalent bond. Purified blood components can be provided by extraction and purification from blood sample or produced by recombinant techniques. The preferred blood component is a blood protein, and more preferably, serum albumin.

[0041] The present invention further relates to method for treating glycaemic-related diseases or disorders, comprising the administration of insulin derivatives or insulin conjugates. Glycaemic-related diseases or disorders include diabetes of Type I and II, and gestational diabetes. Also, cystic fibrosis, polycystic ovary syndrome, pancreatitis and other pancreas-related diseases may also be treated by the administration of insulin derivatives or insulin conjugates of the present invention. Insulin is also known as a growth factor and therefore, the insulin derivatives or insulin conjugates of the present invention can be useful in topical administration for wound healing and other related indications.

[0042] The following examples are for the purpose of further illustrating the invention as described above rather than for the purpose of limiting the scope of the present invention.

EXAMPLES

[0043] Fig. 1 illustrates the insulin molecule and the Gly A1, Phe B1 and Lys B29 sites referred to along the following examples.

Example I

Synthesis of (Gly A1)-MPA-Insulin

[0044] Insulin (100 mg) was dissolved in DMF(dimethylformamide) (2 mL) and TFA (100 uL). To the solution, NMM (4-methylmorpholine, 200 uL) and MPA-OSu (N-succinimidyl 3-maleimidopropanoate, 9.2 mg 2.5 equivalents) were added and the reaction was stirred for 2 h. The reaction was quenched by addition of water and adjusted to pH 4 with AcOH(acetic acid). Acetonitrile was added to dissolve the precipitate and the total volume of water/acetonitrile (3:1) was 20 mL. The solution was injected into a semi-preparative HPLC. Phenomenex Luna 10 m phenyl-hexyl 21 mm X 250 mm column equilibrated with an aqueous TFA solution (0.1% TFA in H_2O, solvent A) and an acetonitrile TFA solution (0.1% TFA in acetonitrile, solvent B). Elution was achieved at 9.5 mL/min by running a 27 to 31% B gradient over 120 min. Fractions containing peptides were detected by UV absorbance at 214 and 254 nm. Fractions were collected in 9.5 mL aliquots. Fractions containing the desired product profile were identified by mass detection after direct injection onto LC/MS. The pure fractions at Rt= 36-46 min. were collected, combined and lyophilized to give a white powder (40 mg) along with 23 mg of recovered insulin.

[0045] Mass calculated is 5958.5 g/mol, and measured by LC-MS is 5958.0 g/mol.

[0046] Table 1 show the amino acid sequence analysis (Edman degradation using phenylisothiocyanate) that was performed to confirm that the A-chain N-terminal was blocked and B-chain N-terminal (phenylalanine) was still free.

Table 1

Compound	Chain	Edman Degradation Results (Positions)			
		1	2	3	4
Human Insulin	A	Gly	Ile	Val	Glu
	B	Phe	Val	Asn	Gln
Example I	A	--	--	--	--
	B	Phe	Val	Asn	Gln
Example II	A	Gly	Ile	Val	Glu
	B	--	--	--	--
Example III	A	Gly	Ile	Val	Glu
	B	--	--	--	--
Example IV	A	Gly	Ile	Val	Glu
	B	Phe	Val	Asn	Gln

Table 1 presents the structural elucidation via Edman degradation of example I to IV

Example II

Synthesis of (Phe B1)-MPA-Insulin

[0047] Insulin (100 mg) was dissolved in DMSO (dimethylsulphoxide) (4 mL) and Et_3N (triethylamine) (100 uL) with sonication. To the solution, Boc_2O (Di-tert-butyl dicarbonate) (9.3 mg, 2.5 equivalents) was added and the reaction was stirred at ambient temperature for 30 min. The reaction was quenched by addition of water (15 mL) and acetonitrile (5 mL) and the solution was adjusted to pH 4 with AcOH. The solution was injected into a semi-preparative HPLC. Phenomenex Luna 10 m phenyl-hexyl 21 mm X 250 mm column equilibrated with an aqueous TFA solution (0.1% TFA in H2O, solvent A) and an acetonitrile TFA solution (0.1% TFA in acetonitrile, solvent B). Elution was achieved at 9.5 mL/min by running a 27 to 40% B gradient over 120 min. Fractions containing peptides were detected by UV absorbance at 214 and 254 nm. Fractions were collected in 9.5 mL aliquots. Fractions containing the desired product profile were identified by mass detection after direct injection onto LC/MS. Three products (Boc-insulin, Gly A1Lys B29-BisBoc-insulin and TrisBoc-insulin) were isolated and the fractions of desired (GlyA1 Lys B29)-BisBoc-insulin were combined and lyophilized to give a white powder (72 mg).

[0048] (Gly A1 Lys B29)-BisBoc-Insulin (51 mg) in DMF (3 mL) was reacted with MPA-OSu (36 mg) in the presence of Et_3N (30 uL). The reaction was stirred for 2 h at ambient temperature. DMF was evaporated by a under vacuum. The residue was treated with TFA (2 mL) for 10 min. and then TFA evaporated. The crude product was dissolved in water/acetonitrile (3:1) and the solution injected into a semi-preparative HPLC. Phenomenex Luna 10 m phenyl-hexyl 21 mm X 250 mm column equilibrated with an aqueous TFA solution (0.1% TFA in H2O, solvent A) and an acetonitrile TFA solution (0.1% TFA in CH3CN, solvent B). Elution was achieved at 9.5 mL/min by running a 27 to 32% B gradient over 120 min. Fractions containing peptides were detected by UV absorbance at 214 and 254 nm. Fractions were collected in 9.5 mL aliquots. Fractions containing the desired product profile were identified by mass detection after direct injection onto LC/MS. The pure fractions were combined and lyophilized to give a white powder (29 mg).

[0049] Mass calculated is 5958.5 g/mol, and measured by LC-MS is 5958.4 g/mol.

[0050] The amino acid sequence analysis (Edman degradation using phenylisothiocyanate) was used to confirm that the B-chain N-terminal was blocked and A-chain N-terminal (glycine) was still free(see table 1).

Example III

Synthesis of (B1)-MPA-OA-insulin

[0051] (Gly A1 Lys B29)-BisBoc-Insulin (39 mg) in DMF (3 mL) and Et_3N (30 uL) was reacted with MPA-OA-OSu ([N-succinimidyl 8-N-(3-maleimidopropanylcarbonyl)AminoOctanoate] 25 mg) for 4 h. DMF was evaporated and the residue treated with TFA for 10 min. After evaporation of TFA, the residue was dissolved in water/acetonitrile (1:3). The solution was injected to a semi-preparative HPLC. Phenomenex Luna 10 m phenyl-hexyl 21 mm X 250 mm column equilibrated with an aqueous TFA solution (0.1% TFA in H2O, solvent A) and an acetonitrile TFA solution (0.1% TFA in acetonitrile, solvent B). Elution was achieved at 9.5 mL/min by running a 27 to 36% B gradient over 120 min. Fractions containing peptides were detected by UV absorbance at 214 and 254 nm. Fractions were collected in 9.5 mL aliquots. Fractions containing the desired product profile were

identified by mass detection after direct injection onto LC/MS. The pure fractions were combined and lyophilized to give a white powder (21 mg).

[0052] Mass calculated is 6099.5 g/mol, and measured by LC-MS is 6099.6 g/mol.

Example IV

Synthesis of (Lys B29)-MPA-Insulin

[0053] Insulin (74 mg) was dissolved in DMSO (2 mL) and AcOH (46 uL). To the solution Boc_2O (6.9 mg, 2.5 equivalents) was added and the reaction was stirred for 5 h at room temperature. Water (15 mL) and acetonitrile (5 mL) were added and the solution was injected to a semi-preparative HPLC column (C18 phenyl-hexyl) in flow rate of 9.5 mL/min and with gradient from 27-40% over 120 min. The fractions at 43 min. were combined and lyophilized to give (Gly A1 Phe B1)-Boc2-Insulin (30 mg).

[0054] (Gly A1 Phe B1)-Boc_2-Insulin (30 mg) in DMF (2 mL) and NMM (4-methylmorpnoline, 100 uL) was reacted with MPA-OSu (10 mg) for 60 min. DMF was evaporated and the residue treated with TFA for 10 min. The residue was dissolved in water/acetonitrile (3:1) and the solution injected to a semi-preparative HPLC. Phenomenex Luna 10 m phenyl-hexyl 21 mm X 250 mm column equilibrated with an aqueous TFA solution (0.1% TFA in H_2O, solvent A) and an acetonitrile TFA solution (0.1% TFA in acetonitrile, solvent B). Elution was achieved at 9.5 mL/min by running a 27 to 32% B gradient over 120 min. Fractions containing peptides were detected by UV absorbance at 214 and 254 nm. Fractions were collected in 9.5 mL aliquots. Fractions containing the desired product profile were identified by mass detection after direct injection onto LC/MS. The pure fractions were combined and lyophilized to give a white powder (22.2 mg).

[0055] Mass calculated is 5958.5 g/mol, and measured by LC-MS is 5958.0 g/mol.

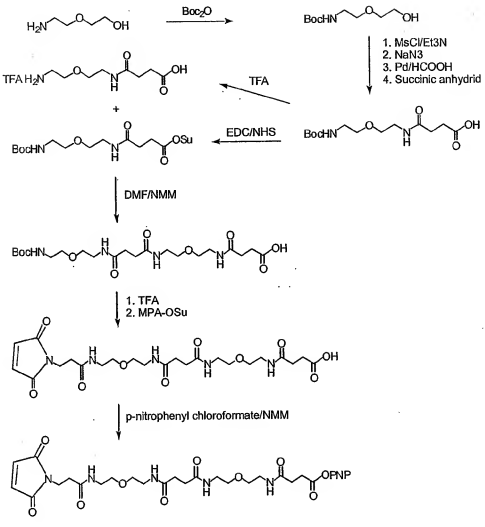
[0056] The amino acid sequence analysis (Edman degradation using phenylisothiocyanate) was used to confirm that both B-chain (phenylalanine) and A-chain (glycine) N-termini were free (see table 1).

Example V

Synthesis of MPA-(AEES)$_2$-COOH linker

[0057] Flash column chromatography was carried out using a Biotage® "40i flash chromatography" modular system. Semi preparative HPLC purifications were done on a Waters "Breeze" system 1500 series using a Phenomex luna (RP-18, 10 u phenyl-hexyl 250 X 21.2 mm) column with a 9.5 mL/min mobile phase flow rate. A Gilson 690 system was used for preparative scale purification using a Phenomex luna (RP-18, 10 u phenyl-hexyl 250 X 50.0 mm) column with a 50 mL/min mobile phase flow rate. A Gradient of acetonitrile (CH_3CN) (0.1%TFA) in water (0.1%TFA) was used with further details indicated in each compound's synthetic procedure. LC-MS was performed using an Agilent 1100 series LC-MSD single quadrupole mass spectrometer with an ES1 electrospray source.

MPA-(AEES)$_2$-COOH linker synthesis



Example VI

Synthesis of (Phe B1)-MPA-$(AEES)_2$-Insulin

[0058] 2-(2-Aminoethoxy)ethanol (50.0 g) in methanol (150 mL) was reacted with Boc_2O (93.4 g) for 30 min. The methanol was evaporated in vacuo and the residue was taken up in ethyl acetate, washed with water, brine and dried with sodium sulfate. After evaporation of the solvent, the crude product was used for the next step. MS m/z 205.

[0059] The protected alcohol was dissolved in N,N-dimethyl formamide (500 mL) in the presence of Et_3N (66 mL). MsCl (Mesylate chloride) (33.4 mL) was added dropwise at 0°C over 30 min and then stirred at ambient temperature for 1 h. NaN_3 (127.6 g) was then added to the reaction mixture followed by NMM (N-methylmorpholine, 215 mL) and the reaction was stirred at 40-50°C for 16 h. The reaction mixture was poured into ethyl acetate (2L) and washed with water. The water layer was back extracted with ethyl acetate (2L) and the combined ethyl acetate layers were washed with water, brine and dried. After evaporation of the solvent, the crude product was used for the next step (101.4 g contains some DMF). MS m/z 231.

[0060] The crude product (62.4 g) was dissolved in methanol (300 mL) followed by the addition of $Pd(OAc)_2$ (3.0g) and formic acid (96% 62 g). After completion of the reaction, Pd species were removed by filtration through celite. The methanol was removed in vacuo and dried further under vacuum. The crude product was used in the next step.

[0061] The crude product was dissolved in dichloromethane and neutralized by Et_3N until it is basic. Succinic anhydride (32.3 g) was added in one portion. The reaction was stirred at ambient temperature for 1 h. The solvent was removed in vacuo and the residue acidified by HCl 1N to pH 3. The product was extracted with ethyl acetate. The ethyl acetate layer was passed through a silica gel plug (1 kg). Then the silica gel was washed with 2-4% methanol in ethyl acetate. The pure fractions (as judged by thin layer chromatography) were combined and the solvent removed in vacuo to give Boc-AEES as an oily residue (36 g, 44%). MS m/z 305

[0062] Boc-AEES (5.5 g) was treated with N-hydroxysuccinimide (NHS, 4.57 g) and ethyl-(dimethylaminopropyl)carbodiimide hydrochloride (EDC, 7.62 g) in dichloromethane (30 mL) for 2 h. The NHS ester was poured into ethyl acetate (500 mL), washed with 0.1 N HCl and dried with sodium sulfate. The solvent was removed in vacuo and the residue used as such in the next step.

[0063] Boc-AEES (6.05 g) was treated with trifluoroacetic acid (TFA, 10 mL) for 10 min. TFA was removed in vacuo and dried further under vacuum. The (AEES) amino acid in was dissolved in N,N-dimethylformamide (20 mL) and basified with excess NMM. The crude product from example V was then added and the reaction was stirred at ambient temperature for 1 h. The solvent was evaporated under reduced pressure and the residue was injected into preparative HPLC using a 5-40% gradient over 60 min. The solvent was removed and the residue dried under vacuum to give Boc-$(AEES)_2$-COOH as an oil (5,64 g, 84%). MS m/z 478.

[0064] Boc-$(AEES)_2$-COOH (3.60 g) was treated with trifluoroacetic acid (TFA, 10 mL) for 10 min. TFA was removed in vacuo and dried further under vacuum. The $(AEES)_2$ amino acid in was dissolved in N,N-dimethylformamide and basified with NMM. MPA-OSu (2.94 g) was added and the mixture was stirred for 30 min. N,N-dimethylformamide was removed under vacuum. The residue was dissolved in water and injected into preparative HPLC using a 5-40% gradient over 60 min. The pure fraction were combined and the solvent was removed to give MPA-$(AEES)_2$-COOH as an off-white solid (3.8 g, 95%). MS m/z 542.2.

[0065] MPA-$(AEES)_2$-COOH (3.04 g) was dissolved in N,N-dimethylformamide (20 mL) and the presence of NMM (1.13 mL) and treated with p-nitrophenyl chloroformate (1.13 g). The reaction mixture was stirred at ambient temperature for 2 h. N,N-dimethylformamide was removed under vacuum. The residue was purified by flash column chromatography using Biotage® system. The column was rinsed with ethyl acetate (500 mL) followed by 10% methanol in ethyl acetate (1 L). The pure fractions were combined and the solvent removed to give MPA-$(AEES)_2$-CO_2PNP as a solid (1.39 g, 37%). MS m/z 663.

[0066] Gly A1, Lys B29-BisBoc-Insulin (200 mg) in N,N-dimethylformamide (10 mL) was coupled with MPA-$(AEES)_2$-CO_2PNP from example VIII (200 mg) in the presence of NMM (200 uL) at ambient temperature for 16 h. N,N-dimethylformamide was removed under vacuum and the residue treated with TFA for 10 min. TFA was removed in vacuo, the residue was dissolved in water and injected into HPLC using a 27-32% gradient over 120 min. The pure fractions were combined and the solvent lyophilized to give (Phe B1)-MPA$(AEES)_2$-Insulin as a white powder (95.0 mg, 43.7%). MS m/z 6330.4.

Example VII

Synthesis of (B29)-MPA(AEES)2-Insulin

[0067] Gly A1 Phe B1-BisBoc-Insulin (200 mg) in N,N-dimethylformamide (10 mL) was coupled with MPA-$(AEES)_2$-CO2PNP as from Example VI (200 mg) in the presence of NMM (200 uL) at ambient temperature for 16 h. N,N-dimethylformamide was removed under vacuum and the residue treated with TFA for 10 min. After TFA was removed in vacuo, the residue was dissolved in in water and injected into HPLC using a 27-32% gradient over 120 min. The pure fractions were combined and the solvent lyophilized to give (Lys B29)-MPA$(AEES)_2$-Insulin as a white powder (56.3 mg, 25.9%). MS m/z 6328.8.

Example VIII

Synthesis of (B29)-MPA(OA)-Insulin

[0068] Gly A1 Phe B1-BisBoc-Insulin (205 mg) in N,N-dimethylformamide (10 mL) was coupled with MPA-OA-CO_2Su (139 mg) in the presence of NMM (20 uL) at ambient temperature for 16 h. The solvent was removed under vacuum and the residue treated with TFA for 10 min. After TFA was removed in vacuo, the residue was dissolved in in water and injected into HPLC using a 27-36% gradient over 120 min. The pure fractions were combined and the solvent lyophilized to give (Lys B29)-MPA(OA)-Insulin as a white powder (64.2 mg, 31%). MS m/z 6098.8.

Example IX

In vitro binding assays

[0069] Liver membranes of Wistar rats were incubated with [125I] insulin and increasing concentrations of insulin, DAC:insulin as described in Fig. 1 and their corresponding conjugate for 16 hours at 4°C. The membranes were filtered and washed 3 times and the filters were counted to determine [125I] insulin specifically bound. IC50 were calculated using GraphPad Prism software.

[0070] The results of IC50 are illustrated in Table 2.

Table 2

	IC50 (nM)
Insulin	12.0
Example I	57.1
Example II	18.8
Example III	17.2
Example IV	46.0
Example VI	24.9
Example VII	58.1
Example VIII	64.1
Conjugate of Example I	2059.0
Conjugate of Example II	100.5
Conjugate of Example III	87.7
Conjugate of Example IV	1190.0
Conjugate of Example VI	38.5
Conjugate of Example VII	508.2
Conjugate of Example VIII	1013.4

[0071] Fig. 2 and Fig. 3 illustrates the insulin binding in rat liver membrane in terms of the % of inhibition in function of the concentration of the insulin derivative of the present invention.

Example X
In vitro bioactivity

[0072] Glucose uptake in adipocytes was used to evaluate the in vitro activity. 3T3-L1 cells, a murine fibroblast cell line was differenciated in adipocytes for used in the bioassay. 3T3-L1 cells were plated and grown to confluency in DMEM and 10% FBS, followed by an incubation for two days. Differentiation was induced by adding dexamethasone and insulin (D0). By day 7, more than 90% of the cells displayed an adipocyte phenotype, i.e. accumulation of lipid droplets. Figs. 4A-4C show preadipocytes, cells after 3 days and adipocytes at 7 days. Figs. 5A and 5B show oil red o staining of adipocytes at 4 days and adipocytes at 7 days. Figs. 6A and 6B show oil red o and methylene blue staining at 4 days and at 7 days.

[0073] 3T3-L1 adipocytes were starved overnight in DMEM containing 5mM glucose and 0.5% FBS. Cells were rinsed in Kreb's-Ringer-Hepes buffer containing 1% BSA and incubated with increasing concentrations of insulin, DAC:insulin derivatives and their corresponding conjugate for 20 minutes at 37°C and with [^{14}C]-2-deoxy-D-glucose (1μCi/well) for an additional 20 minutes. Cells were solubilized and radioactivity was measured. Glucose uptake (%) was calculated versus insulin control and EC50 were calculated using GraphPad Prism™ software.

[0074] Table 3 show the EC50 results for the compounds tested and Fig. 7 illustrates the glucose uptake in % of control in function of the concentration (M) of the compounds.

Table 3

Compound	EC50 (nM)
Human insulin	1.2
Example III	34
Conjugate of Example III	48
Example IV	45
Conjugate of Example IV	110

Example XI

[0075] In addition, glucose uptake in an other source of adipocytes was used to evaluate the in vitro activity. Epididymal fat obtained from Wistar derived male rats weighing 175 ± 25 g is used. The tissue (0.03 g/ml) is degraded by collagenase in modified HEPES solution pH 7.4 at 37°C. Test compound and/or vehicle is incubated with 500 µl aliquots in modified HEPES buffer pH 7.4 and D-[3-3H]Glucose (2.5 µCi/ml) is then added for 2 hour incubation. Test compound-induced the increase of glucose incorporation by more than 50 percent or more (≥50%) relative to the control 2 nM insulin response, indicates possible insulin receptor agonist activity. Test compound inhibition of the insulin-induced glucose incorporation response by more than 50% indicates insulin receptor antagonist activity. Compounds are screened at 10, 1, 0.1, 0.01 and 0.001 µM.

[0076] Table 4 show the EC50 results for the compounds tested and Fig. 8 illustrates the glucose uptake in % of control in function of the concentration (M) of the compounds.

Table 4

Compound	EC50 (nM)
Human insulin	1.4
Example III	17.5
Conjugate of Example III	17.8
Example VI	15.4
Conjugate of Example VI	13.3

Example XII

In vivo experiments

[0077] Evaluation the blood glucose lowering efficacy of recombinant human insulin versus and insulin derivatives of the present invention when administered subcutaneously to diabetic female db/db mice, are compared.

[0078] Tested compounds were administered by a single subcutaneous bolus injection in 5-6 week-old female db/db mice weighing 24.3 to 33.3 g. The average volume of dosing solution injected was 0.35 mL/mouse (12.5 mL/kg).

[0079] Recombinant (E. coli) human insulin (called herein below "rH insulin") is provided by ICNTM at a concentration of 28 IU/mg.

[0080] Stock solutions of insulin derivatives were prepared at 14.29 mg/mL (~ 400 IU/mL) by reconstituting the synthesized insulin derivatives with acidified water (~ pH 2). Stock solutions were subsequently diluted with 0.9% NaCl and 0.22 µm filtered (Millex GV) to obtain the dosing solutions shown in Table 5. Group 1 received 0.9% NaCl USP as control solution.

Table 5

Groups	Tested Compounds	Actual Solution Concentration (mg/mL)
2	rH Insulin	0.29
3	Example I	0.29
4	Example I	1.43
5	Example II	0.29
6	Example II	1.43
7	Example III	0.29
8	Example III	1.43

[0081] Groups and treatments are summarized in the Table 6.

Table 6

Groups	Test/Control Articles	Dose Level (mg/kg)	Dose Equivalence *(~IU/kg)	Number of Animals (females)
1	0.9% NaCl	0	0	5
2	rH insulin	3.6	100	5
3	Example I	3.6	100	5
4	Example I	17.9	500	5
5	Example II	3.6	100	5
6	Example II	17.9	500	5
7	Example III	3.6	100	5
8	Example III	17.9	500	5

* Based on the potency of the rH insulin estimated at 28 IU/mg by the vendor.

[0082] Blood sampling (one drop) was performed via the tail tip and glucose levels were determined using a hand-held glucometer (Model: One Touch UltraTM, Lifescan Canada). Blood glucose levels were determined from all animals once prior to administration (pre-dose), and at 1, 2, 3, 4, 6, 24, 30, 48 and 72 hours post-dose.

In vivo results:

[0083] All animals appeared normal prior to administration of the tested compounds. Approximately one hour post-dose, Group 2 of animals treated subcutaneously with 100 IU/kg of recombinant human insulin (rH insulin), exhibited slight decrease in activity and uncoordinated gait. Other treated animals appeared normal throughout the experiment. A slight decrease of food consumption was observed in animals treated with 17.9 mg /kg of compound of Example III.

[0084] Table 7 shows food consumption (total weight/cage (g)) following a single administration of rH insulin and insulin derivatives.

Table 7
Food consumption: total weight/cage (g)

Groups	Treatment	24h pre-dose	0-6h	0-24h	24-48h	48-72h
1	0.9% NaCl	30.4	6.2	30.7	28.9	31.6
2	rH insulin 3.6 mg/kg	30.2	6.6	29.2	30.7	31.7
3	Example I 3.6 mg/kg	28.7	5.8	30.5	28.8	28.7
4	Example I 17.9 mg/kg	29.8	5.1	28.3	31.3	31.5
5	Example II 3.6 mg/kg	31.8	6.4	30.3	29.8	31.0
6	Example II 17.9 mg/kg	30.5	6.4	31.2	26.5	29.7
7	Example III 3.6 mg/kg	29.9	6.0	31.4	31.9	31.8
8	Example III 17.9 mg/kg	28.7	4.5	27.0	22.8	24.5

[0085] Table 8 shows food consumption versus control (total weight/cage (g)) following a single administration of rH insulin and insulin derivatives.

Table 8

% Food consumption *versus* control group

Groups	Treatment	24h pre-dose	0-6h	0-24h	24-48h	48-72h
1	0.9% NaCl	100.0	100.0	100.0	100.0	100.0
2	rH insulin 3.6 mg/kg	99.3	106.5	95.1	106.2	100.3
3	Example I 3.6 mg/kg	94.4	93.5	99.3	99.7	90.8
4	Example I 17.9 mg/kg	98.0	82.3	92.2	108.3	99.7
5	Example II 3.6 mg/kg	104.6	103.2	98.7	103.1	98.1
6	Example II 17.9 mg/kg	100.3	103.2	101.6	91.7	94.0
7	Example III 3.6 mg/kg	98.4	96.8	102.3	110.4	100.6
8	Example III 17.9 mg/kg	94.4	72.6	87.9	78.9	77.5

[0086] Delta glycaemia is calculated from blood glucose levels of post-dose glucose level versus the pre-dose glucose level for each individual mouse are reported in Figs 9, 10, 11, 12, 13, and 14. In general, insulin derivatives (Example I, Example II and Example III) were able to lower blood glucose concentrations in a dose-dependent manner and recombinant insulin, tested at one dose level only (100 IU/kg), was active for 2 hours. At 3.6 mg/kg, Example 2 was as active as insulin during the first 2 hours while only a marginal effect was observed with Example I and Example III. The lowering effect of rH insulin was more pronounced at 17.9 mg/kg since it was observed for up to 24 hours. Although the overall picture tends to demonstrate that insulin derivatives were active for up to 24 hours (as compared to the control group), it is important to note that glucose levels decreased at 1-2 hours post-dose then increased at 3-4 hours and decreased again at 6 hours. This 'up and down' response might indicate that the feeding habits and the metabolism of the mice are important parameters that can affect the efficacy of the drug.

It is important to mention that db/db mice develop insulin resistance with age, which could explain the very high dose of insulin that had to be injected to observe glucose lowering effect.

Example XIII

Pharmacokinetic profile in normal rats

[0087] Rh insulin, the insulin derivative of example III and the conjugate of the insulin derivative of Example III were administered to 7-8 week-old male CD rats either at 36 nmol/kg sc or 12 nmol/kg intravenously (iv). Blood samples were collected up to 72 hours (only up to 3 hours for rh insulin-treated animals). The drug levels were determined using a human insulin ELISA kit (Linco). The pharmacokinetic parameters were calculated by non-compartmental analysis using the WinNonlin software, N=4 rats per compound/route. Fig. 15 is the pharmacokinetic profile of insulin in normal SD rats where insulin was administered sc at 36 nmol/kg and iv at 12 nmol/kg. Fig. 16 is the pharmacokinetic profile of the conjugate of example III in normal SD rats where the conjugate was administered sc at 36 nmol/kg and iv at 12 nmol/kg. Fig. 17 is the pharmacokinetic profile of the insulin derivative of example III in normal SD rats where the insulin derivative was administered sc at 36 nmol/kg and iv at 12 nmol/kg. Fig. 18 is the subcutaneous PK profile of the administration of insulin, insulin derivative of example III and the conjugate of the insulin derivative of example III. Fig. 19 is the intravenous PK profile of the administration of insulin, insulin derivative of example III and the conjugate of the insulin derivative of example III.

Example XIV

Single dose pharmacodynamic in diabetic rats

[0088] Diabetes was induced in male CD rats with a single i.v. injection of streptozotocin (60 mg/kg). Two days later, rats received a single sc injection of DAC™:Insulin derivatives at 120 nmol/kg, preformed conjugates at 300 nmol/kg, rh insulin at 20U/kg (120 nmol/kg) or vehicle. Blood glucose level were measured with a hand-held glucometer just prior injection and a 1, 2, 3, 4, 6, 8, 10, 11, 24, 30 and 48 hours postdose with 5

rats/groups except for vehicle were 3 rats/ group were tested. Glycemia of normal rats ranged from 5.2 to 7.6 mmol/L.

[0089] Figs. 20 shows the blood glucose level in rats after administration of 120nmol/kg of example I to IV. Fig 21 shows the blood glucose level in rats after administration of the corresponding conjugate of example I toIV of the present invention at 300nmol/kg.

Example XV

Evaluation of the potency of a DAC:Insulin derivative and its corresponding preformed conjugate following repeated subcutaneous administration

[0090] This assay was conducted to evaluate the potency of the insulin derivative of the example III and its conjugate versus free human recombinant insulin following repeated subcutaneous injections in adult male CD® rats.

[0091] Type 1 diabetes was induced in male CD® rats on study day 1 by a single intravenous (i.v.) injection of streptozotocin (60 mg/kg, pH 4.5). Hyperglycemia was confirmed using a blood glucose monitor to test blood. Test compound was administered once daily on study days 3 through 14 at 1 mL/kg body weight by subcutaneous (s.c.) injection. Blood glucose levels were tested just prior to dose administration each day and at 2,8 and 18 hours following administration. Feed and water consumption were monitored daily. Body weights were collected on study days 1, 3, 6, 9, 12, 15 and 17.

[0092] Fig. 22 illustrates the blood glucose daily profile at day 1, 6 and 12 for the insulin derivative of example III and Fig. 23 illustrates the blood glucose daily profile at day 1, 6 and 12 for the conjugate of the insulin derivative of example III.

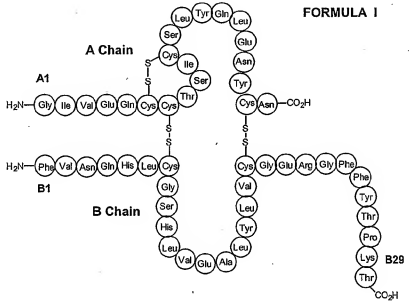
[0093] While the invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modifications and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to

which the invention pertains and as may be applied to the essential features hereinbefore set forth, and as follows in the scope of the appended claims.

WHAT IS CLAIMED IS:

1. An insulin derivative comprising an insulin molecule and a reactive group for covalently bonding a blood component.

2. The insulin derivative of claim 1, wherein the insulin molecule is of formula I:



and the reactive group is coupled to an amino acid of the insulin molecule at a position selected from the positions Gly A1, Phe B1 and Lys B29.

3. The insulin derivative of claim 1 or 2, wherein the reactive group is selected from the group consisting of Michael acceptor, a succinimidyl-containing group and a maleimido-containing group.

4. The insulin derivative of claim 3, wherein the Michael acceptor is an α,β, unsaturated carbonyl moiety.

5. The insulin derivative of claim 1 or 2, wherein the reactive group is a maleimido-containing group.

6. The insulin derivative of claim 1 or 2, wherein the reactive group is 3-Maleimidopropionic acid (MPA).

7. The insulin derivative of any one of claims 1 to 6, wherein the reactive group is coupled to an amino acid of the insulin molecule via a linker.

8. The insulin derivative of claim 7, wherein said linker is selected from the group consisting of (2-amino) ethoxy acetic acid (AEA), ethylenediamine (EDA), amino ethoxy ethoxy succinimic acid (AEES), AEES-AEES, 2-[2-(2-amino)ethoxy)] ethoxy acetic acid (AEEA), AEEA-AEEA, $-NH_2-(CH_2)_n-COOH$ where n is an integer between 1 and 20 and alkyl chain (C1-C10) motif and combination thereof.

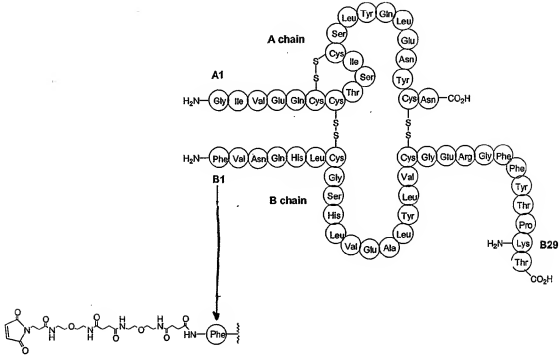
9. The insulin derivative of claim 8, wherein said alkyl chain (C1-C10) motif is one or more alkyl chains (C1-C10) saturated or unsaturated in which could be incorporated oxygen nitrogen or sulfur atoms.

10. The insulin derivative of claim 9, wherein said alkyl chain is selected from the group consisting of glycine, 3-aminopropionic acid (APA), 8-aminooctanoic acid (AOA) and 4-aminobenzoic acid (APhA).

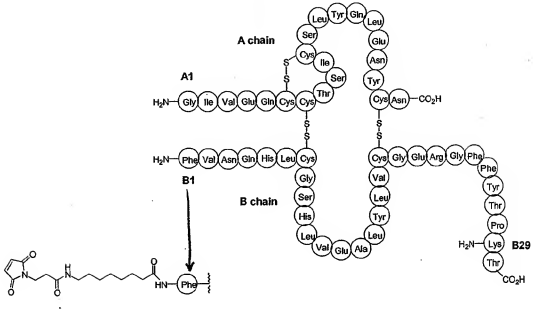
11. The insulin derivative of claim 8, wherein said combination is selected from the group consisting of AEEA-EDA, AEEA-AEEA and AEEA-AEEA.

12. The insulin derivative of claim 6, wherein said linker is $-NH_2-(CH_2)_7-COOH$.

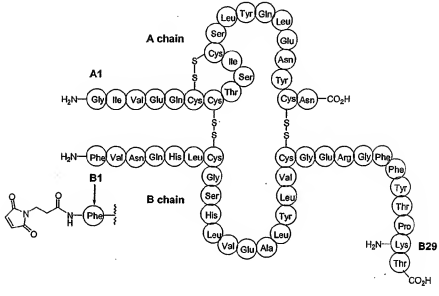
13. The insulin derivative of claim 1 having the formula:



14. The insulin derivative of claim 1, having the formula:



15. The insulin derivative of claim 1, having the formula:



16. The insulin derivative of claim 1, wherein said blood component is a blood protein.

17. The insulin derivative of claim 16, wherein said blood protein is serum albumin.

18. An insulin conjugate comprising an insulin derivative according to any one of claims 1 to 17 and a blood component, wherein the reactive group and the blood component are conjugated through a covalent bond formed between said reactive group and said blood component.

19. The insulin conjugate of claim 18, wherein the blood component is a blood protein.

20. The insulin conjugate of claim 19, wherein the blood protein is serum albumin.

21. The insulin conjugate of claim 18, wherein said conjugate was formed *ex vivo*.

22. A pharmaceutical composition comprising the insulin derivative of any one of claims 1 to 17 in association with a pharmaceutically acceptable carrier.

23. A pharmaceutical composition comprising the insulin conjugate of any one of claims 18 to 21 in association with a pharmaceutically acceptable carrier.

24. A method for treating a glycaemic-related disease or disorder in a subject suffering from said glycaemic-related disease or disorder, comprising administering the insulin derivative of any one of claims 1 to 17 to said subject.

25. The method according to claim 24, wherein said glycaemic-related disease is selected from the group consisting of diabetes of type I,

diabetes of type II, gestational diabetes, cystic fibrosis, polycystic ovary syndrome and pancreatitis.

26. The method according to claim 24, wherein the glycaemic-related disease is selected from the group consisting of diabetes of type I and diabetes of type II.

27. A method for treating a glycaemic-related disease or disorder, comprising the administration of the insulin conjugate of any one of claims 18 to 21.

28.. The method according to claim 27, wherein said glycaemic-related disease is selected from the group consisting of diabetes of type I, diabetes of type II, gestational diabetes, cystic fibrosis, polycystic ovary syndrome and pancreatitis.

29. The method according to claim 27, wherein the glycaemic-related disease is selected from the group consisting of diabetes of type I and diabetes of type II.

30. A method for treating a glycaemic-related disease or disorder, comprising the administration of the pharmaceutical composition of any one of claims 22 and 23.

31. The method according to claim 30, wherein said glycaemic-related disease is selected from the group consisting of diabetes of type I, diabetes of type II, gestational diabetes, cystic fibrosis, polycystic ovary syndrome and pancreatitis.

32. The method according to claim 30, wherein the glycaemic-related disease is selected from the group consisting of diabetes of type I and diabetes of type II.

33. Use of the derivative of any one of claims 1 to 17, for the preparation of a medicament for the treatment of a glycaemic-related disease or disorder.

34. The use as claimed in claim 33, wherein said glycaemic-related disease is selected from the group consisting of diabetes of type I, diabetes of type II, gestational diabetes, cystic fibrosis, polycystic ovary syndrome and pancreatitis.

35. The use as claimed in claim 33, wherein the glycaemic-related disease is selected from the group consisting of diabetes of type I and diabetes of type II.

36. Use of the conjugate of any one of claims 18 to 19, for the preparation of a medicament for the treatment of a glycaemic-related disease or disorder.

37. The use as claimed in claim 36, wherein said glycaemic-related disease is selected from the group consisting of diabetes of type I, diabetes of type II, gestational diabetes, cystic fibrosis, polycystic ovary syndrome and pancreatitis.

38. The use as claimed in claim 37, wherein the glycaemic-related disease is selected from the group consisting of diabetes of type I and diabetes of type II.

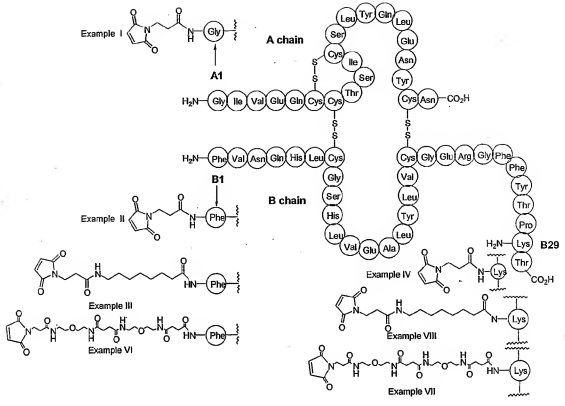

Example I
A chain
A1
B1
B chain
Example II
Example III
Example VI
Example IV
Example VIII
Example VII
B29

Fig. 1

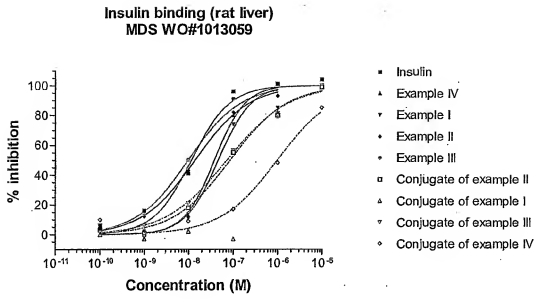

Insulin binding (rat liver)
MDS WO#1013059
% inhibition
100
80
60
40
20
0
10-11 10-10 10-9 10-8 10-7 10-6 10-5
Concentration (M)
Insulin
Example IV
Example I
Example II
Example III
Conjugate of example II
Conjugate of example I
Conjugate of example III
Conjugate of example IV

Fig. 2

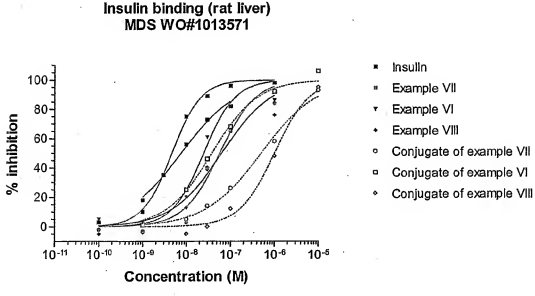

Insulin binding (rat liver)
MDS WO#1013571
% inhibition
100
80
60
40
20
0
10-11 10-10 10-9 10-8 10-7 10-6 10-5
Concentration (M)
Insulin
Example VII
Example VI
Example VIII
Conjugate of example VII
Conjugate of example VI
Conjugate of example VIII

Fig. 3

Preadipocytes 32X

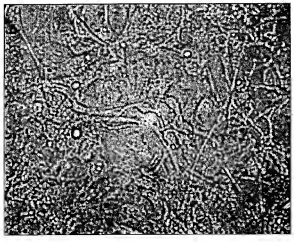


Fig. 4A

3 days treatment

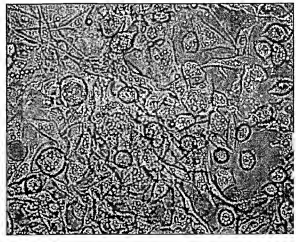


Fig. 4B

Adipocytes (D7)

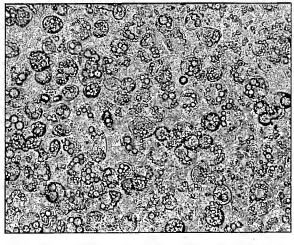


Fig. 4C

Adipocytes (D4)

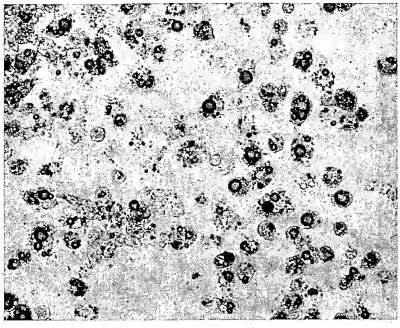


Fig. 5A

Adipocytes (D7)

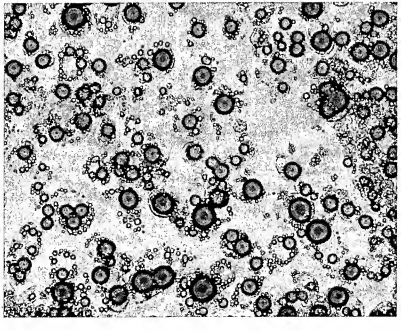


Fig. 5B

Adipocytes (D4)

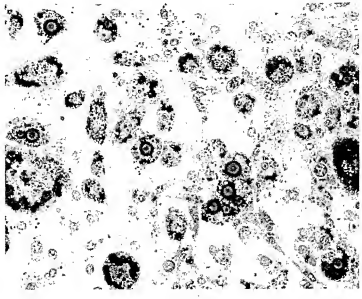


Fig. 6A

Adipocytes (D7)

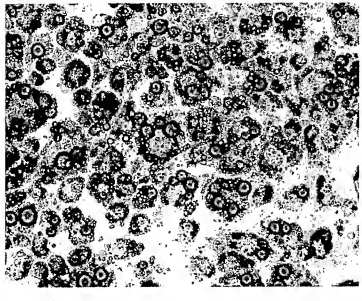


Fig. 6B

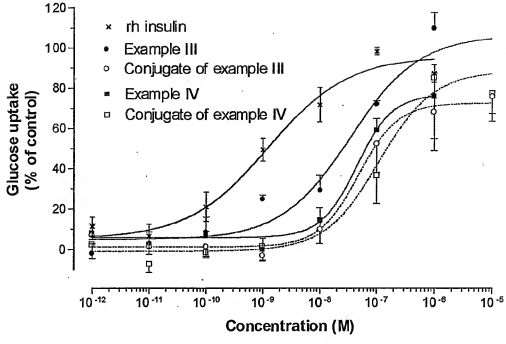

rh insulin
Example III
Conjugate of example III
Example IV
Conjugate of example IV
Glucose uptake (% of control)
120
100
80
60
40
20
0
10-12
10-11
10-10
10-9
10-8
10-7
10-6
10-5
Concentration (M)

Fig. 7

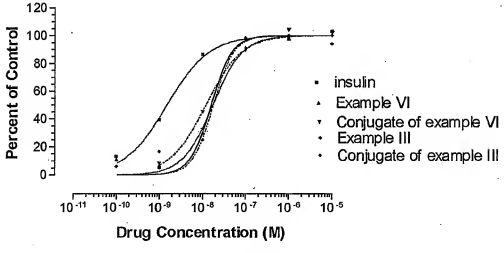

insulin
Example VI
Conjugate of example VI
Example III
Conjugate of example III
Percent of Control
120
100
80
60
40
20
0
10-11
10-10
10-9
10-8
10-7
10-6
10-5
Drug Concentration (M)

Fig. 8

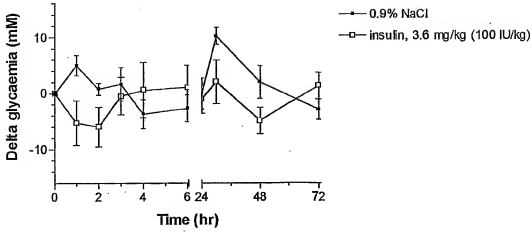

0.9% NaCl
insulin, 3.6 mg/kg (100 IU/kg)
Delta glycaemia (mM)
10
0
-10
0
2
4
6
24
48
72
Time (hr)

Fig. 9

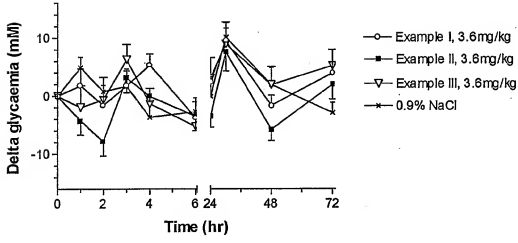

Example I, 3.6mg/kg
Example II, 3.6mg/kg
Example III, 3.6mg/kg
0.9% NaCl
Delta glycaemia (mM)
10
0
-10
0
2
4
6
24
48
72
Time (hr)

Fig. 10

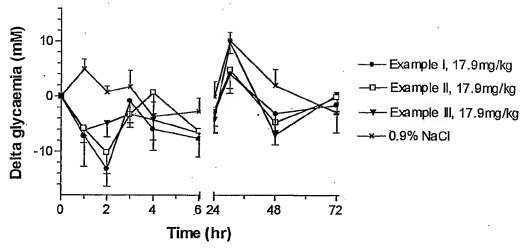

Delta glycaemia (mM)
10
0
-10
0
2
4
6
24
48
72
Time (hr)
Example I, 17.9mg/kg
Example II, 17.9mg/kg
Example III, 17.9mg/kg
0.9% NaCl

Fig. 11

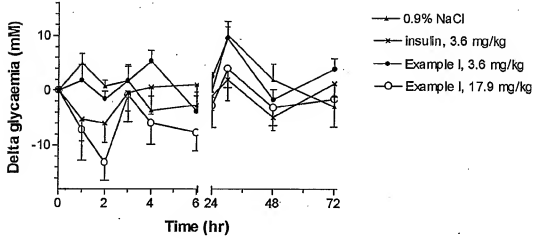

Delta glycaemia (mM)
10
0
-10
0
2
4
6
24
48
72
Time (hr)
0.9% NaCl
Insulin, 3.6 mg/kg
Example I, 3.6 mg/kg
Example I, 17.9 mg/kg

Fig. 12

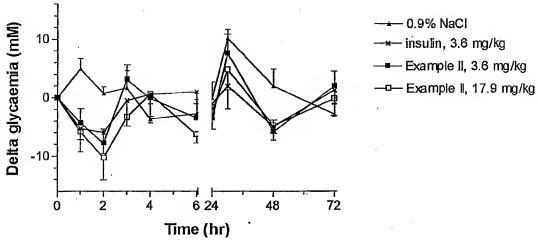


Fig. 13

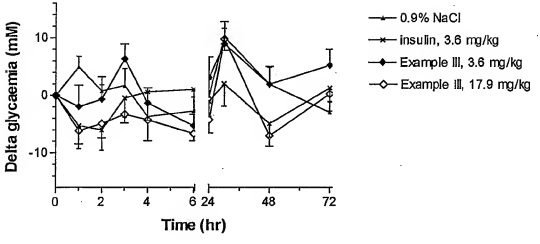


Fig. 14

Data insulin nM

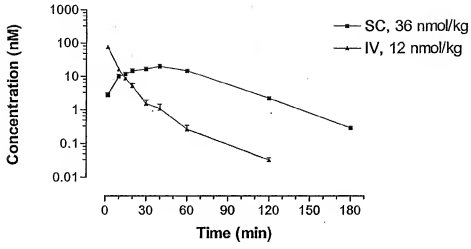

Concentration (nM)
1000
100
10
1
0.1
0.01
0
30
60
90
120
150
180
Time (min)
SC, 36 nmol/kg
IV, 12 nmol/kg

Fig. 15

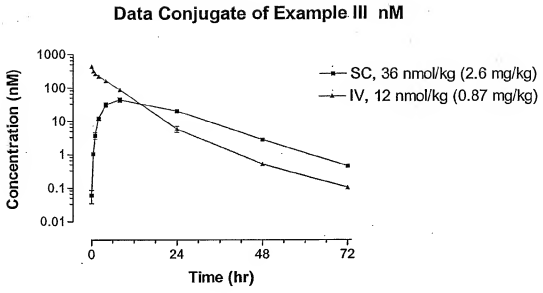

Data Conjugate of Example III nM
Concentration (nM)
1000
100
10
1
0.1
0.01
0
24
48
72
Time (hr)
SC, 36 nmol/kg (2.6 mg/kg)
IV, 12 nmol/kg (0.87 mg/kg)

Fig. 16

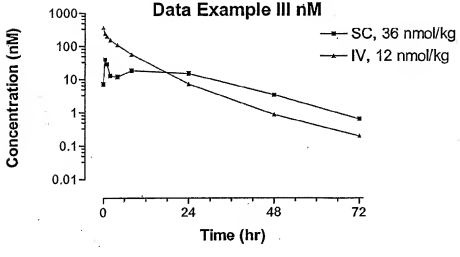

Data Example III nM
Concentration (nM)
1000
100
10
1
0.1
0.01
0
24
48
72
Time (hr)
SC, 36 nmol/kg
IV, 12 nmol/kg

Fig. 17

Example III / Conjugate of Example III/ Insulin

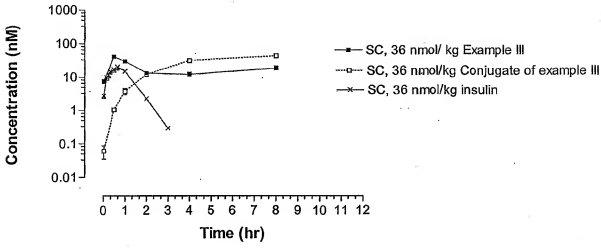


Fig. 18

Example III / Conjugate of Example III / Insulin

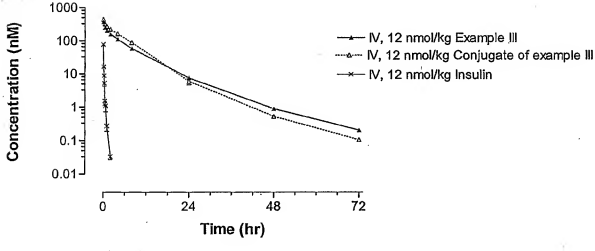


Fig. 19

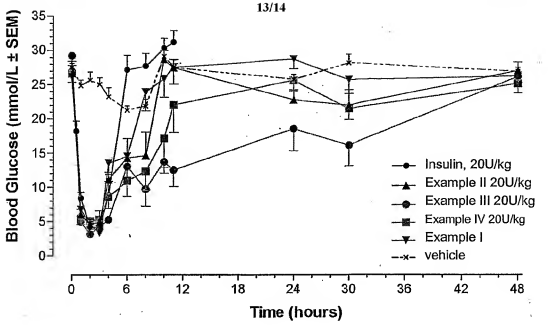

Blood Glucose (mmol/L ± SEM)
Time (hours)
Insulin, 20U/kg
Example II 20U/kg
Example III 20U/kg
Example IV 20U/kg
Example I
vehicle

Fig. 20

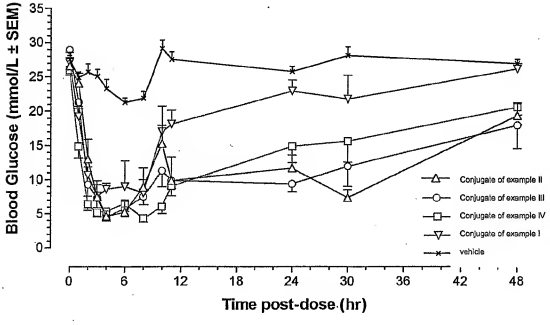

Blood Glucose (mmol/L ± SEM)
Time post-dose (hr)
Conjugate of example II
Conjugate of example III
Conjugate of example IV
Conjugate of example I
vehicle

Fig. 21

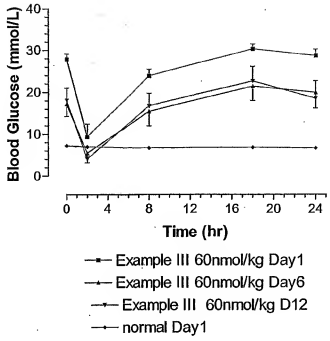

Blood Glucose (mmol/L)
40
30
20
10
0
0
4
8
12
16
20
24
Time (hr)
Example III 60nmol/kg Day1
Example III 60nmol/kg Day6
Example III 60nmol/kg D12
normal Day1

Fig. 22

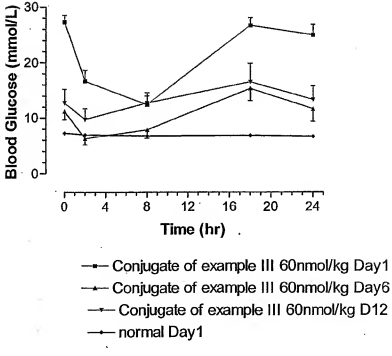

Blood Glucose (mmol/L)
30
20
10
0
0
4
8
12
16
20
24
Time (hr)
Conjugate of example III 60nmol/kg Day1
Conjugate of example III 60nmol/kg Day6
Conjugate of example III 60nmol/kg D12
normal Day1

Fig. 23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2004/001409

A. CLASSIFICATION OF SUBJECT MATTER
IPC[7] C07K-14/62, C07K-14/765, A61P-3/10, C07K-1/113, A61K-38/28, A61P-5/50

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC[7] C07K-14/62

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)
Canadian Patent Database; EPOQUE; DELPHION; ESP@CENET; CA PLUS
Key words: "insulin derivative"; "insulin analog"; " insulin analogue"; "insulin conjugate"; "long lasting"; "protracted"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95 05187 A1 (UNITED MEDICAL & DENTAL SCHOOLS OF GUYS AND ST. THOMAS' HOSPITALS) 23 February 1995 whole document	1, 2, 7, 16-23, 33-38
Y		3-6, 8-15
X	CA 2334859 A1 (KINGS COLLEGE LONDON; DEUTSCHES WOLLFORSCHUNGS INSTITUT) 23 December 1999 whole document	1-3, 7, 16, 18, 19, 21-23, 33-38
Y		4-6, 8-15, 17, 20
X	JONASSEN ET AL. "Fatty acid acylated insulins display protracted action due to binding to serum albumin." In: PEPTIDE SCIENCE: PRESENT AND FUTURE, PROCEEDINGS OF THE INTERNATIONAL PEPTIDE SYMPOSIUM, 1ST KYOTO, NOV. 30, 1997, (1999), MEETING DATE 1997, pages 674-677. EDITOR: SHIMONISHI, YASUTSUGA. PUBLISHER: KLUWER DORDRECHT, NETH. whole document	1-3, 7, 16-23, 33-38
Y		4-6, 8-15

Further documents are listed in the continuation of Box C.

Patent family members are listed in annex.

* Special categories of cited documents :
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international-type search	Date of mailing of the international-type search report
10 November 2004 (10-11-2004)	~~10 November 2004 (10-11-2004)~~ 21 December 2004

Name and mailing address of the ISA/ *Commissioner of Patents* *Canadian Patent Office - PCT* *Ottawa/Gatineau K1A 0C9* Facsimile No. 1-819-953-9358	Authorized officer Colleen MacFarlane (819) 997-4614

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2004/001409

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BAUDYS ET AL. "Extending insulin action *in vivo* by conjugation to carboxymethyl dextran." BIOCONJUGATE CHEMISTRY. 1998, vol. 9, pages 176-183 whole document	1-3, 7, 16, 18, 19, 21-23, 33-38
Y		4-6, 8-15, 17, 20
Y	CA2363712 A1 (CONJUCHEM INC.) 23 November 2000 whole document	1-23, 33-38
Y	UCHIO ET AL. "Site specific insulin conjugates with enhanced stability and extended action profile." ADVANCED DRUG DELIVERY REVIEWS 35 (1999), vol. 35(2,3), pages 289-306 whole document	1-23, 33-38
Y	US 6323311 B1 (LIU ET AL.) 27 November 2001	1-23, 33-38
Y	US 3868357 A (SMYTH ET AL.) 25 February 1975	1-23, 33-38
Y	US 3868356 A (SMYTH ET AL.) 25 February 1975	1-23, 33-38
P,X	THIBAUDEAU ET AL. "Development of novel DAC™ insulin analogues with extended pharmacodynamic profiles." AMERICAN DIABETES ASSOCIATION 64TH SCIENTIFIC SESSIONS. ABSTRACT 488-P, June 4-8, 2004, ORLANDO, FLORIDA	1-23, 33-38

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2004/001409

Box No. II **Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons :

1. [X] Claims Nos. : 24-32
because they relate to subject matter not required to be searched by this Authority, namely:

Claims 24-32 are directed to methods of treatment of the human/animal body. (Article 17(2)(a)(i) and Rule 39.1(iv) PCT)

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically :

3. [ ] Claims Nos. :
because they are dependant claims and are not drafted in accordance with the second and third sentences of Rule

Box III **Observation where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows :

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos. :

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos. :

Remark on Protest
[ ] The additional search fees were accompanied by the applicant's protest.
[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on petent family members

International application No.
PCT/CA2004/001409

Patent document cited	Publication Date	Family Members	PublicationDate
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Continuation of Form PCT/ISA/210 (patent family annex):

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